An Optical Survey of the Position Error Contours of Unidentfied High Energy Gammma-ray Sources at Galactic Latitude b> |20°|

S. D. Bloom [1], D. A. Dale [2], R. Cool [2,3], K. Dupczak [2], C. Miller [2], A. Haugsjaa [2], C. Peters [1], M. Tornikoski [4], P. Wallace [5], M. Pierce [2]

ABSTRACT

We present results from our optical survey of the position error contours ("error boxes") of unidentified EGRET sources at mid to high Galactic latitude. It is our intention to search for potential blazars that may have been missed in the original identification process of the three EGRET Catalogues and supplementary publications. We have first searched the error contours of unidentified sources at $b > |20°|$ for flat spectrum radio sources using the NASA Extragalactic Database (NED). For each such radio source found we conducted optical searches for counterparts using the Palomar 60-inch telescope, and University of Wyoming's 2.3 and 0.6 m telescopes. Many of the radio sources have plausible optical counterparts, and spectroscopy will be conducted at a later date to determine which of these sources are quasars or active galaxies. Results show thats several sources are optically variable, and/or have flat or inverted radio to millimeter spectra and are thus potential blazars.

Subject headings: gamma rays: observations

1. Introduction

Though the EGRET instrument detected 271 sources, most of these sources remain unidentified with counterparts at any other wavelength (Hartman *et al.* 1999). However, the distribution of these sources on the sky does suggest at least two major populations: Those near the Galactic plane, where 90 % of the sources are unidentified, and those above the plane, where 50 % are unidentified (Caraveo 2001). Caraveo (2001) further suggest that those sources above the plane may have at least three subcomponents: extragalactic, Gould Belt, and Galactic halo. Though nearly all of the firmly identified extragalactic sources are blazars, there have been some recent studies suggesting

---

[1]Department of Physics & Astronomy, Hampden-Sydney College, Box 821, Hampden-Sydney, VA 23943

[2]Department of Physics & Astronomy, University of Wyoming, Laramie, Wyoming 82070

[3]Steward Observatory, University of Arizona, Tucson, AZ 85721

[4]Metasahovi Radio Observatory

[5]Department of Physics & Astronomy, Berry College, Mount Berry, GA 30149

that some sources are related to non-blazar AGN (Mukherjee *et al.* 2002) or galaxy clusters (Colafrancesco 2002). The task of investigating all of these sources seems daunting. Therefore, several investigators have gone the route of examining several individual sources in depth. An advantage of this approach is that such searches are like to yield abundant information on the several sources they investigate; however, it is more difficult to draw general conclusions from such results. We continue along these lines by searching within the error contours of high Galactic latitude EGRET unidentified sources for new blazars. We will then ascertain whether any such objects found are likely to be the source of the gamma rays. At the time of submission, we became aware of a parallel study by Sowards-Emmerd, Romani, & Michelson (2003). Though similar in scope, ours studies differ, and are complimentary, in that we are continuing multi-epoch optical observations with B, V, R photometry and do include some sources at southern declinations.

2. Source Selection

Using the NASA Extragalactic Database (NED), we have searched for flat spectrum radio sources (spectral index,$-0.5 < \alpha < 0.5$) within the 95 % positional confidence contours of EGRET unidentified sources with $|b| > 20°$. Unless otherwise mentioned, spectral indices referred to in this paper are between 1.4 and 5 GHz. Aside from a handful of pulsars and relatively nearby extragalactic sources, blazars with flat radio spectra are the only objects that have been detected by EGRET as a class. Though not all flat spectrum sources are blazars, it remains a good way of separating out possible blazars from a much larger group of radio sources. We have chosen this range of Galactic latitudes so that there will be minimal overlap with Galactic populations discussed in the introduction and fewer problems with optical identification in crowded fields. It should be noted, however, that EGRET blazar candidates have been found in the Galactic plane (Halpern *et al.* 2001).The radio data referenced in NED were usually from the Green Bank Surveys, which had positional acccuracies of about 1-3 arcminutes (depending on the observing frequency and the source brightness). This resolution is far too coarse for conducting optical searches. We have therefore additionally searched for these sources in the NRAO VLA Sky Survey (NVSS) in order to obtain positions accurate to approximately 1 arcsecond, which can be achieved for sources brighter than 15 mJy (Condon *et al.* 1998). In addition to the flat spectrum radio sources, we have compiled a secondary observing list of radio sources of unknown spectral index, and or X-ray and optical sources with accurate positions.

After applying these criteria, 53 EGRET sources remain in the potential sample (unidentified in the Third EGRET Catalogue), with an average of about 1 candidate radio source within the position error contours of the EGRET source. In addition, there are 18 AGN's with questionable identifications. We further restricted ourselves to the ranges of right ascension and declination that were visible from Mount Palomar during the nights in November 1999 and from the Wyoming telescopes during the subsequent nights in 2002. These limits lead us to exclude all sources with declination below -30 ° , leaving us with 41 unidentified sources and 13 with questionable identifica-

tions. The right ascension limits are somewhat less strictly determined since we observed at several different points during the year. However, Northern Hemisphere summer months were those most deliberately avoided (usually due to poor sky conditions). Sources in the 18h to 0h range would be least covered by the observations (about half of the remaining sources).

An extensive study of the identification of radio sources with EGRET sources was conducted by Mattox *et al.* (1997); Mattox, Hartman & Reimer (2001). Essentially they conclude that it is difficult to positively identify a gamma-ray source with any radio source with flux density less than about 500 mJy at 5 GHz mostly because the sky density of such sources is so high that the probability for chance correlations is correspondingly high. They assume that the radio spectra would be near their peak fluxes at these frequencies, and thus that the 5 GHz flux densities would be representative of the peak synchrotron output of the source. This assumption was likely partially made out of necessity, since there are no complete high frequency surveys with sensitivity less than 1 Jy. However, other investigators have shown that several sources might be fairly dim at these low frequencies and have a brighter (and flatter, more variable) spectrum extending to at least 200 GHz (Tornikoski *et al.* 2002; Bloom *et al.* 1997, 2000). Thus some dim 5 GHz sources, which by the method of Mattox *et al.* (1997); Mattox, Hartman & Reimer (2001) would not be considered to be counterparts to EGRET sources may indeed be counterparts to gamma-ray blazars. We intend to make up for this deficiency by searching for optical counterparts to radio sources that may be dim (in some cases, < 100 mJy) at 5 GHz. If a counterpart is found we will search for blazar-like activity, and go on to investigate the optical and radio spectra of these objects.

3. Observations

We began conducting the search for optical counterparts on 3-4 November 1999 using the 60-inch telescope at Mount Palomar with a Tek 2048 x 2048 CCD. The pixel size in this set-up is 0.37 arc seconds; however, we have binned the pixels 2-by-2 to an effective size of 0.74 arc seconds. Since the seeing for those nights (and most at Palomar) was worse than 1 arc second, no crucial information on source structure was lost. In addition, we would expect most of our sources to be point-like. We have used the Johnson B, V, and Kron R filters for determining magnitudes in those bandpassses. The procedure was to first observe a candidate source in R for 10 minutes (and then adjust to shorter or longer exposures depending on the results). If no obvious counterpart was found after 20 minutes, we did not go to the other filters. If a potential source was seen, we observed in V and B as well. In addition to the program sources, we have observed Landolt standard stars throughout the evening to determine the photometric scale and atmospheric absorption (Landolt 1992).

At Red Buttes (RBO) imaging was completed using an SBIG ST-6 CCD Camera. The ST-6 was mounted at Cassegrain focus, as is the common user mode at RBO. The pixels were 27 μm by 23 μm with a field of view of 4.7 arcminutes x 6.2 arcminutes. The plate scale is 1.14 arcseconds x 0.97 arcseconds. Standard filters, as described above, were used. Again, standard stars were used

to calibrate source magnitudes (Landolt 1992).

At the Wyoming Infrared Observatory (WIRO), an Apogee-AP8 camera was used on the 2.3 m. A new configuration, WIRO-Prime, was used in which camera was mounted at prime focus, giving a 18 arcminutes x 18 arcminutes field of view (Pierce *et al.* 2002). The pixel size of 24 x 24 μm^2 gave a plate scale of 1 arc second per pixel. The seeing in May 5, 2002 ranged between 2-3 arcseconds throughout the night. Filters identical to those used at RBO were used for multicolor photometry.

Data reduction was carried out uisng the standard photometry packages in the Image Reduction and Analysis Facility (IRAF). The atmospheric extinction values for airmass and color corrections were calculated using the STELLARPHOT package developed and maintained by Cornell University.

In addition, some sources with high enough 5 GHz flux were additionally observed at 37 GHz, at the Metsahovi Observatory in Finland, and at 90 GHz using SEST in Chile (see Tornikoski *et al.* (2002) for more information on the observing procedure at those telescopes). These results are discussed below in Section 5.

J. Halpern (Columbia University) has provided us with the optical spectrum of one source, NVSS J032850+212825. The data were acquired at the KPNO 2.1 m on 23 Oct 2001 using the Goldcam spectrograph and Ford 3K x 1K pixel CCD with 15 micron pixels. The spectrograph uses a grating of 500 l/mm, blaze 550 angstroms and resolution of 5 angstroms. The slit width is 1.9 arcseconds. More details of the spectographic set up can be obtained at http://www.noao.edu/kpno/manuals/l2mspect/spectro The significance of this particular spectrum is discussed below.

4. Analysis

Our first goal in the analysis was to locate potential matches between the NVSS radio sources and an optical source. Clearly, this could only be achieved once an absolute coordinate system was established for the images (discussed below). The approximate radio source position accuracy is given by:

$$\sigma_p = \frac{0.5\theta\sigma_s}{S}$$

where σ_p is the position uncertainty, θ is the Gaussian beam size in arc seconds, σ_s is the uncertainty of the flux and S is the 1.4 GHz flux from the NVSS. If we subsitute in approximate numbers, $\theta = 40$, $\sigma_s/S = 25$, then $\sigma_p = 0.8$. We thus have to acheive accuracy somewhat better than this to be certain of an optical coincidence with a radio source. Practically speaking, if the offset between the NVSS position and optical position is much greater than this uncertainty (typically 0.5-1.0 arc seconds for our sample), we can not be very confident in our match. We have matched the optical images to the coordinate scale of the USNO-A2.0 catalogue using the XTRAN routine within

AIPS. Tables 1-3 show the results for each telescope. Most of the radio sources have plausible visual counterparts; however some have large uncertainty of coincidence between the radio and optical source. Below, we consider the most likely matches to the gamma ray source (if any). We have also quantified the amplitude of the optical variability with the parameter:

$$A \equiv \frac{F_{max} - F_{min}}{F_{max} + F_{min}}$$

Where the F values correspond to the minimum or maximum flux at a particular waveband. A factor of 2 in variabilty ccorresponds to $A = 0.333$. Though we also include the USNO magnitudes for comparison in the individual source notes below, we note that this is primarily for qualitative comparison to the current measurements. In particular, Monet *et al.* (2003) estimate an overall uncertainty in photometry of 0.25 mag in the USNO catalog. However, the photometry of extended sources is considerably worse, and even that of stars can be worse if there are no photometric standard stars on or overlapping the plate of interest. Since many of our identifications are extended sources, we cautiously conclude that even marginal variability (when using USNO catalog magnitudes) can not be suggested unless $\Delta mag \sim 1$ or greater. We have also included information on the known gamma-ray variability of the EGRET sources, in the form of the δ statistic of Nolan *et al.* (2003). This statistic divides the standard deviation of the flux by the average for a specific gamma-ray source. For each source, a most likely value of δ, and a 68% confidence interval are determined assuming a gamma distribution for the fluxes. They also calculate a probability that the source shows variability consistent with being beyond that caused by systematic uncertainty alone . They define a statistic, V_{12}, described by the following equation, that allows for a less cumbersome representation of the probabilities:

$$V_{12} = -log_{10}[1 - P_{\chi^2}(r|1)]$$

Here, $P_{\chi^2}(r|1)$ refers to the cummulative χ^2 probability distribution with one degree of freedom. See Nolan *et al.* (2003) for justification of using this probability distribution. With these parameters, $\delta > 1$ with $V_{12} > 1$ are likely to be truely variable. To contextualize these numbers more clearly, 3C 279, which is widely considered as a highly variable source, has $\delta = 0.9$ and $V_{12} = \infty$. The Crab Pulsar, a steady source, has $\delta = 0.08$, and V_{12} is undetermined because δ is below that expected from systematic uncertainty alone. $\delta = 0$ or near 0 implies non-variability within the systematic uncertainty of gamma-ray fluxes. $V_{12} = \infty$ implies a 0 (or nearly) probability of the source being constant. We disucss this analysis below in the context of possible multiwavelength variability of each source.

5.   Notes on Individual Sources

3EG J0038-0949.- NVSS J003906-094247 is the most plausible counterpart for this source, and is the only possible blazar counterpart discussed in the literature thus far (Mattox, Hartman &

Reimer 2001). The optical and NVSS positions are offset by 0.83 arcseconds (approximately same as NVSS position uncertainty). Reimer *et al.* (2003) consider the possibility that this source is associated with the A85 galaxy cluster, however conclude that it is likely to be a chance coincidence. The flux at 5 GHz is approximately 0.2 Jy , $\alpha = -0.1$. This source exhibits marginal night to night optical variability, as indicated in Table 1. We also note the possible long term variability, particlarly in B, as determined from the comparison to the USNO magnitudes from 1954 (B=19.4; R=19.1). The other possible identification we consider (PMN J0037-1010; NVSS J003750-101034) is a much weaker (0.04 Jy at 5 GHz) and steeper spectrum radio source ($\alpha = -0.7$). Additionally, this source shows no evidence for optical variability. In this case, the optical and NVSS sources are offset by 2.5 arcseconds, and thus the radio/optical match is somewhat questionable. The γ-ray variability ($\delta = 0$) is insignificant .

3EG J0215+1123.- We consider two potential identifications for this object. Though the QSO B0214+108 (4C 10.06) is a moderately strong Green Bank Survey source at 5 GHz (0.44 Jy), the two nearest (and apparently related) compact NVSS object are significantly offset from the optical source (45 arc seconds). The spectral index is -0.8, steeper than expected for a typical blazar. However, this source has been detected recently at 37 GHz with a flux of 0.3 Jy. This source was not detected at 90 GHz (implying a flux <0.4 Jy). This is the only possible identification mentioned by Mattox, Hartman & Reimer (2001). The complex radio structure of 4C 10.06 has been likened to relatively nearby wide-tailed radio galaxies whose radio structure is created by interaction with an intergalactic medium. In this particular case, the QSO may be related to a cluster of galaxies (Hintzen 1984). This would open up the possibility that at least some of the γ-ray emission (and X-ray flux as well) is not directly related to the AGN (Nolan *et al.* 2003).

The other possible identification, NVSS J021527+112318, has a flux of only 0.132 Jy at 5 GHz, but also has been detected at 0.3 Jy level at 37 GHz, thus indicating a rising, and/or variable spectrum. This source was not detected at 90 GHz (flux < 0.4 Jy). The optical and NVSS positions are offset by 4.17 arcseconds and thus somewhat suspect (a few times the uncertainty). If, however, 4C 10.06 is the source of the γ-rays, there may be a high frequency blazar compenent to that radio source that isn't apparent in the surveys, that only show the extended low frequency source. Night to night variability for the QSO related to 4C 10.06 (in R only) is evident at the $4 - \sigma$ level. The USNO magnitudes do not strongly suggest long term variability (B=18.6, R=16.9). Note that these candidates are in addition to the identification favored by Sowards-Emmerd, Romani, & Michelson (2003), which we have not observed. Gamma-ray variability is observed ($\delta = 1.27$, with $V_{12} = 2.10$).

3EG J0245+1758.-The most plausible identification is NVSS J024640+180144. This radio source has flux of about 0.2 at 5 GHz and $\alpha = 0.1$. Sowards-Emmerd, Romani, & Michelson (2003) list this as a potential identification. No BVR night to night variability is seen; however, a possibility of long term variability is suggested by the USNO magnitudes. The optical and NVSS positions ar offset by 1.03 arcseconds (comparable to the uncertainties in position). A second potential identification would be NVSS J024437+17221, however this source is very dim at 5 GHz (0.033 Jy ;$\alpha = -0.1$). This source also shows no evidence for optical night to night variability

or long term variability, considering both the USNO magnitudes (B=19.6; R=18.9) and recent measurements with RBO. The γ-ray variability is marginal ($\delta = 1.14$; $V_{12} = 1.38$).

3EG J0329+2149.-We find that NVSS J032850+212825 is a potential identification.Though this is a dim radio source at 5 GHz (0.057 Jy), we find it additionally interesting because it is an X-ray (ROSAT) and infrared (2MASS) source as well. Punsly (1999) argue that this source, among others, may be an intermediately peaked BL Lac object (IBL), producing X-rays in a relativistic jet. Such sources would be expected to have relatively large X-ray fluxes even if the radio source is weak. As explained in Punsly (1999) and references therein, an IBL could have relatively strong magnetic fields, leading to relatively low radio flux, but relatively higher optical through X-ray flux as compared to blazars that have spectral peaks at lower frequencies (LBL) It was not detected at 37 GHz during recent observations at Metsahovi, implying a flux below 0.2 Jy. This source was also not detected at 90 GHz, implying a flux below 0.4 Jy. The optical and NVSS positions are offset by 3.59 arcseconds (a few times the uncertainty). A recent optical spectrum (Figure 1) shows evidence for a redshifted Ca II H & K feature at 5200 angstroms (z=0.31), though the feature is weak. Imaging shows that this object is extended, and thus is likely at z < 0.3 (Halpern et al. 2003). We therefore consider the redshift to plausible for this object. In addition to the extended appearance of the objects, the infrared colors of 2MASS suggest the source is non-stellar (Tokunaga 2000). Sowards-Emmerd, Romani, & Michelson (2003) suggest a different source for the identification. No short term optical variability is indicated in our data, nor is there any significant difference in our magnitudes and those of the USNO catalogue. The source is not variable in gamma rays ($\delta = 0$).

3EG J0622-1139.-The radio source has already been reported as a possible identification (Bloom et al. 2000), but we present a new epoch of visual data. These data, and the colors of 2MASS suggest the source is non-stellar (Tokunaga 2000). This source is marginally variable in gamma rays ($\delta = 1.04$; $V_{12} = 1.08$)

3EG 0852-1216.- PMN J0850-1213 was reported as an identification by Halpern & Eracleous (1997), and subsequently seen to be highly variable in optical and radio/millimeter (Halpern & Eracleous 1997; Bloom et al. 1997). The optical and NVSS sources are offset by 0.16 arcseconds (much less than the uncertainties in position). We present a new epoch of visual data here, and conclude that the object was in a low optical state at the time of these observations. The history of this object points out that some ordinary Green Bank survey sources can actually be distinguished blazars in disguise. Variability is indicated by the $\delta = 1.21$ and associated probability ($V_{12} = 1.94$).

3EG J1052+5718.- The possible identification with NVSS J105837+562811 was reported previously (Bloom et al. 1997), and we include new optical photometry here. The optical source appears to be significantly dimmer than in the POSS plates (B=14.7, R=14.2). Similar to 3EG J0329+2149 discssed above, this source is also considered to be an IBL by Punsly (1999). This is source shows no γ-ray variability ($\delta = 0.24$; $V_{12} = 0.10$). The optical and NVSS sources are offset by 0.89 arcseconds (approximately same as uncertainties in position).

3EG J1236+0457.- There is a possible identification with B 1237+0404 (NVSS J123934+035020), previously mentioned in Mattox, Hartman & Reimer (2001). We present multicolor photometry for the first time. There are no indications of short or long term optical variability. There is no evidence of γ-ray variability ($\delta = 0.53$; $V_{12} = 0.10$). The optical and NVSS sources are offset by 1.17 arcseconds (approximately same as uncertainties in position).

3EG J1337+5029.- There are no radio sources in this field > 0.045 mJy, however we report on the optical observations of two X-ray sources in the field. These two X-ray sources, and the others in this region appear to be associated with normal galaxies. If the gamma-ray source is related to either of these X-ray sources, but has no radio counterpart, then it must either not be an AGN, or of a type not previously known to have been detected by EGRET. With no further information, we do not consider these sources to be compelling counterparts. The source is not variable in γ rays ($\delta = 0.53$; $V_{12} = 0.41$).

3EG J1600-0351.- A possible identifcation is PMN J1601-0302 (NVSS J160117-030231), with 5GHz flux of 0.06 Jy. This source is coincident with an extended visual (POSS and our survey) and infrared object (2MASS). The radio source is dim at 5 GHz, and is thus not a likely counterpart, based soley on that information. The optical and NVSS sources are offset by 6.21 arcseconds (10 times larger than the uncertainty in position). However, this source should be monitored across the broad band spectrum for signs of blazar activity. This source is not gamma-ray variable ($\delta = 0.01$)

6. Conclusions

We have searched the "error boxes" of EGRET sources, and found several potential blazar counterparts at other wavebands. The most compelling case, newly reported here, is that of 3EG J0038-0949 (matched with NVSS J993906-094247). These counterparts are generally characterized by flat or inverted radio spectra (in some cases up to 37 GHz), and in some cases, long and short term optical variability. We conclude that several of these objects are the source of the gamma rays. This study and others have shown that the EGRET instrument detected a class of dim blazars, in addition to those identified in the Third EGRET Cataloge ((Hartman *et al.* 1999). NASA's upcomming Gamma Ray Large Area Telescope (GLAST) mission should confirm the existence of a relatively dim population of blazars thatare the source of gamma rays for many of the unidentified sources at high Galactic latitude.

REFERENCES

Bloom *et al.* 1997, ApJ, 488, L23

Bloom *et al.* 2000, ApJ, 529, 675

Condon, J. J. *et al.* 1998, AJ, 115, 1693

Caraveo, P. A. 2001, in *Gamma 2001*, eds. S. Ritz, N. Gehrels, C. Shrader p.641

Colafrancesco, S. 2002, A&A,396,31

Halpern, J. E. & Eracleous, M.1997, IAU Circ. 6639

Halpern, J. P., Eracleous, M, Mukherjee, R., Gotthelf, E. V. 2001, ApJ, 551, 1016

Halpern, J. P., Eracleous, M., Mattox, J. R., AJ, 125, 572

Hartman, R. C. *et al.* 1999, ApJS, 123, 79

Hintzen, P. 1984, ApJS, 55, 533

Landolt, A. U. 1992, AJ, 140, 430

Mattox, J. R. *et al.* 1997, ApJ, 481, 95

Mattox, J. R., Hartman, R. C., & Reimer, O. 2001, ApJ, 135, 155

Monet, D. G. et al. 2003, AJ, 125, 984

Mukherjee, R., Halpern, J., Mirabal, N., Gotthelf, E. V. 2002, ApJ, 574, 694

Nolan, P. L., Tompkins, W. F., Grenier, I. A., Michelson, P. F. 2003, ApJ, 597

Pierce, M. J. & Nations, H. L. 2002, BAAS, 200, 64.06

Punsly, B. 1999, ApJ,516,141

Reimer, O., Pohl,M., Sreekumar, P., Mattox, J. R. 2003, ApJ, 588, 155

Sowards-Emmerd, D., Romani, R. W., Michelson, P. F. 2003, ApJ, 590, 109

Tokunaga, A.T. 2000, in Allen's Astrophysical Quantities, p.143

Tornikoski, M. Lahteenmaki, A., Lainela, M., Valtaoja, E. 2002, ApJ, 579, 136

FIGURE CAPTIONS

Fig. 1.— Optical spectrum of NVSS J032850+212825 using KPNO 2.1 m and Goldcam Spectrograph

Table 1.   Observations from the Palomar 60-inch Telescope

EGRET Source (1)	Radio Source (2)	α (3)	δ (4)	Night (5)	Filter (6)	Magnitude (7)	Error (8)	Variability (9)
3EG J0038-0949	NVSS J003750-101034	00:37:50.2	-10:10:36	1	B	21.13	0.06	
					V	19.49	0.03	0.06
					R	18.62	0.02	0.03
				2	B	21.01	0.02	
					V	19.62	0.01	
					R	18.56	0.03	
3EG J0038-0949	NVSS J003906-094247	00:39:06.3	-09:42:48	1	B	23.26	0.43	
					V	20.81	0.06	0.16
					R	19.99	0.08	0.17
				2	V	20.45	0.01	
					R	19.63	0.04	
3EG J0215+1123	NVSS J021527+112318	02:15:27.6	11:23:18	1	B	19.97	0.06	0.22
					V	18.09	0.02	0.06
					R	18.22	0.04	0.42
				2	B	19.58	0.02	
					V	17.96	0.04	
					R	17.23	0.04	
3EG J0245+1758	NVSS J024437+172221	02:44:37.7	17:22:27	1	B	20.00	0.05	0.07
					V	19.43	0.03	0.03
					R	18.58	0.03	0.11
				2	B	20.17	0.07	
					V	19.37	0.01	
					R	18.53	0.07	
3EG J0245+1758	NVSS J024640+180144	02:46:40	18:01:40	1	B	19.64	0.05	
					V	18.08	0.02	0.03
					R	17.29	0.02	
				2	V	18.03	0.01	0.01
					R	17.26	0.03	
3EG J0329+2149	NVSS J032850+212825	03:28:50.6	21:28:24	1	B	19.55	0.08	
					V	18.74	0.03	0.06

Table 1—Continued

EGRET Source (1)	Radio Source (2)	α (3)	δ (4)	Night (5)	Filter (6)	Magnitude (7)	Error (8)	Variability (9)
					R	18.03	0.02	0.003
				2	V	18.60	0.01	
					R	18.03	0.03	

Table 2.   Observations with University of Wyoming Red Buttes Observatory

EGRET Source	Radio Source	Filter	Magnitude	Error
(1)	(2)	(3)	(4)	(5)
3EG J0622-1139	NVSS J061904-114054	V	19.90	0.39
3EG J0852-1216	NVSS J085009-121335	V	19.30	0.22
3EG J1052+5718	NVSS J105837+562811	B	16.83	0.23
		V	16.05	0.15
		R	15.63	0.03

Table 3.   Observations with University of Wyoming Infrared Observatory

EGRET Source (1)	Radio Source (2)	Filter (3)	Magnitude (4)	Error (5)
3EG J1337+5029	1RXS J133510.2+503920	B	17.44	0.04
		V	16.27	0.02
		R	15.66	0.02
3EG J1337+5029	RX J1335.3+5015	B	19.8073	0.04981
		V	18.79	0.02
		R	18.21	0.03
3EG J1236+0457	B1237+0404	B	20.3705	0.07925
		V	20.08	0.07
		R	19.64	0.07
3EG J1600-0351	NVSS J160117-030231	B	17.67	0.04
		V	16.31	0.02
		R	15.43	0.02